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Separations and Fuels Processing

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Multi-Contaminant Removal from Coal Derived Syngas — Meeting Future Environmental and Process Goals —

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Background

Gas cleaning systems have been effectively demonstrated and used in commercial operations for many years. These systems can reduce sulfur (S), mercury (Hg), and other contaminants in synthesis gas produced by gasifiers to the lowest level achievable in coal-based energy systems. Advances in gas cleaning technology are required to meet the U.S. Department of Energy's Fossil Energy goals for increased plant efficiency and lower cost. The gas cleaning goal is to achieve a 2-3 percentage point increase in electric power generation plant efficiency at a cost below current gas cleaning technology. Completion of research and development (R&D), targeted for 2012, will integrate this technology with carbon dioxide (CO_2) separation, capture, and sequestration into a zero-emission configuration(s) and provide the basis for plant designs to produce electricity with less than a 10 percent increase in cost of electricity (COE). To realize these objectives, it is essential to not only reduce contaminant emissions into the generated synthesis gas, but also to increase the process or system operating temperature to that of humid gas cleaning conditions (operation below the syngas dew point of 300 °F to 700 °F (150 °C to 370 °C)), thus reducing the energy penalties that currently exist as a result of lowering process temperatures to -40 °F to 100 °F (-40 °C to 38 °C), with subsequent reheat to the required higher temperatures.

From a historical perspective, advanced syngas cleaning systems applied in integrated gasification combined cycle (IGCC) and chemical/fuel synthesis plants have evolved from configurations of individual cleaning steps, one for each syngas contaminant, with each step controlled to its individual temperature and sorbent/catalyst needs. As the number of syngas contaminants of interest has increased — particulates, hydrogen sulfide (H_2S), carbonyl sulfide (COS), halides such as hydrogen chloride

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(HCl), ammonia (NH_3), hydrogen cyanide (HCN), alkali metals, metal carbonyls, Hg, arsenic (As), selenium (Se), cadmium (Cd)—and the degree of syngas cleaning has become more severe, the potential feasibility of advanced humid gas cleaning has diminished. To reduce the potential cost and enhance performance of humid gas cleaning, research needs to focus on multi-contaminant syngas technologies. Researchers need to consider which syngas contaminants should be removed simultaneously to significantly intensify gas cleaning systems. Intensified, multi-contaminant cleaning processes need to be devised and their potential performance characteristics understood through small-scale testing, conceptual design evaluation, and scale-up assessment.

Objective

The objective of this project is to develop an integrated humid gas cleaning technology approach for next generation IGCC systems. Simultaneous or intensified gas cleaning and removal of major (H_2S, CO_2, etc.), minor (HCl, NH_3, etc.), and trace (Hg, As, Cd, Se, etc.) species is being assessed in order to address whether a potential increase in plant efficiency can be realized, while lowering COE. The National Energy Technology Laboratory's Office of Research and Development (NETL-ORD) is currently developing the following nine gas cleaning technology areas, and researchers are evaluating these technologies relative to commercial technologies, as well as advanced concepts being developed by external contractors:

- Polishing desulfurization with regenerative zinc oxide-based sorbents in fixed-bed systems
- Dechlorination with a regenerative sorbent in fixed- or moving-bed systems
- NH_3 removal with once-through or regenerative sorbent in fixed-bed systems
- Trace metal removal (Hg, As, and Se) using regenerative precious metal sorbents in fixed-bed systems
- Trace metal removal (Hg, As, Se, Cd) using regenerative zinc titanate sorbents in fixed- bed systems
- Simultaneous removal of HCl and H_2S using regenerative sorbent in fixed- or moving- bed systems
- CO_2 capture using magnesium-based sorbent in fluid-bed or moving-bed systems
- CO_2 capture using a solvent (fluorinated hydrocarbons or ionic liquids) in absorber-stripper system
- CO_2 separation in supported ionic liquid membrane systems

As schematically shown in Figure 1, our current system intensification focus addresses further development of candidate technologies that include (1) simultaneous particulate and halide removal, (2) simultaneous sulfur polishing and removal of Hg, As, Se, and Cd, and (3) post-water gas shift (WGS) sorbents, membranes, and solvents for CO_2 capture — thus stream-lining the number of process removal components within the gasifier island. The challenges of sorbent regeneration, cost competitive separation, and multi-functional reactor designs are additional aspects that are concurrently being evaluated in each of these technology areas.

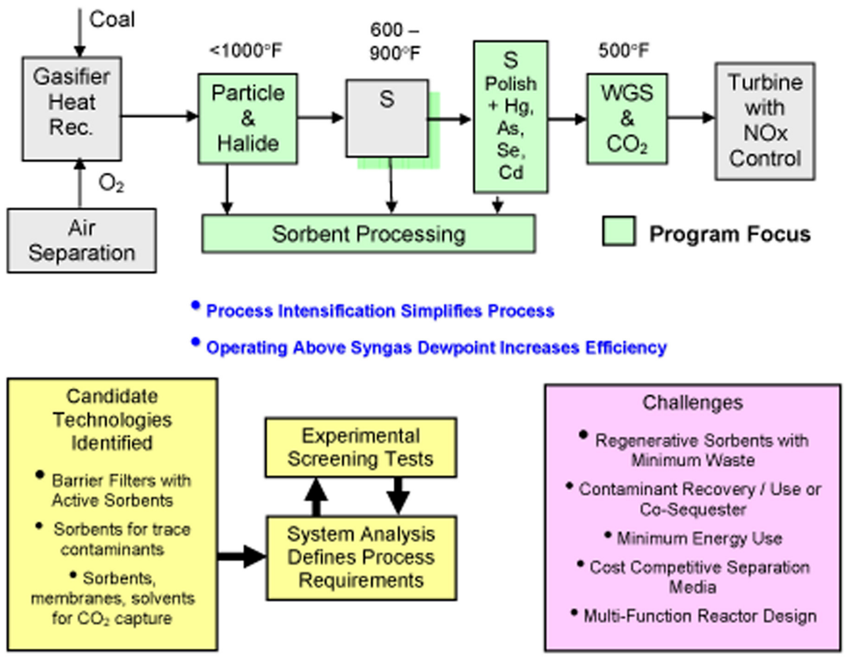

Figure 1 — Next Generation IGCC Plant Gas Cleaning Technology

The FY07 Multi-Contaminant Removal from Coal Derived Syngas project consists of three tasks:

Task 1 — Systems Intensification

- Assess the feasibility of NETL-ORD gas cleaning technology subtask projects relative to commercial process design and performance criteria for advanced IGCC humid gas cleaning concepts.
- Define and analyze process intensification concepts for simultaneous carbon capture and removal of S, NH_3, and trace contaminant species released during coal gasification.
- Identify R&D priorities to address technology gaps.

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- Define critical experiments to provide a basis for process design and scale-up.
- Address reduced development risks of key components.
- Address the fate of contaminants to assure achievement of near-zero emission plant.

Task 2 —Major (Sulfur and Halide) Contaminant Removal

- Develop a HCl removal sorbent to obtain removal efficiency of less than 1 ppm at warm gas temperatures.
- Develop a multi-functional sorbent that could remove H_2S, HCl, and NH_3.
- Develop procedures to process the regeneration gas.
- Demonstrate the sorbent performance.

Task 3 — Trace (Metals) Contaminant Removal

- Continue development of a multi-contaminant sorbent for the capture of Hg, As, Se, and Cd from high-temperature fuel gas.
- Verify the capture of Se at lab-scale.
- Demonstrate simultaneous capture of Hg, As, and Se from simulated fuel gases at lab-scale.
- Optimize the regeneration procedure to restore activity of the sorbents.
- Confirm the hypothesized mechanisms of trace metal capture.
- Demonstrate the removal of Hg, As, Se, and Cd in a gasification facility in collaboration with Johnson Matthey, NETL's Cooperative Research and Development Agreement partner.